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ABSTRACT

The characteristics and components of scientific literacy are reviewed and analyzed in this report. Perspectives are given on textbook use, content, emphases and applications of the dimensions of scientific literacy. The distinctive features of the curriculum reform projects of the 1960's and 1970's are also discussed and their impacts are assessed. A report follows of an investigation that asssessed the extent to which recently published textbooks (1984 to 1986) appeared to promote scientific literacy. Nine elementary science (K-6) textbook series and one non-textbook program were analyzed. Areas reviewed include: (1) science topic coverage; (2) the nature and methods of science; (3) science, technology, and society; (4) content organization; and (5) teaching and learning activities. An examination of the programs indicates that although the programs cover science content, they do not promote or encourage the development of scientific thinking or attitudes nor do they engage students in applying the cognitive processes that are basic to understanding the content covered. (ML)

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"SCIENTIFIC ILLITERACY" IN ELEMENTARY SCIENCE TEXTBOOK PROGRAMS

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There is a growing concern over the quality of schooling in this country and special emphasis has been given recently to finding ways to improve science instruction and student achievement in science. In this paper we present the results of our investigation of ten recently published elementary science series (copyrights 1984-1986). In this investigation we placed particular emphasis on the extent to which these programs address the broad goal of "scientific literacy" through their treatment of the nature of science as a field of inquiry and the ways in which science content and process is introduced to students.

Of all the recommendations made by the Commission on Excellence in Education's A Nation at Risk (1983) and from the host of reports that followed from state departments of education and professional organizations, one point is emphasized over and over again: science education is in trouble and needs substantial reform if the aims of achieving scientific literacy and building a cadre of potential scientists are to be met. For those educators with long memories, the alarm expressed in these reports about the state of science instruction in elementary and secondary schools had a familiar ring. Problems of inadequate teacher training for science instruction and the tendency of many school districts to treat science as a poor relation when compared to reading and mathematics were often cited as problems that interfere with the effective teaching of science at the elementary school level.

Recommendations for improving science instruction have included teacher retraining and career incentives for science specialists, but some reformers see the textbook as a pivotal element in efforts to improve science instruction and student achievement. The choice of textbooks as a vehicle for improvement is not surprising. Qualitative studies by Cahan, Filby, McCutcheon, and Kyle (1984) and Stake and Easley (1979) and quantitative studies by EPIE (1976) and Frymier, Davis, and Clinefelter (1977) show that as much as 90% of instructional time is structured by some sort of instructional materials, especially textbooks. This reliance on textbooks has led researchers to observe that in many school districts and classrooms the textbook is the de facto curriculum. Thus, if a textbook series organizes science instruction in a certain way or emphasizes certain learning activities, the likelihood is that, whatever else the curriculum may mandate, what is in the textbooks is what teachers will teach and science students will learn--especially at the elementary school level where many of the teachers are not science specialists.

Previous Critiques of "Textbook Science"

In work related to that being reported here, Woodward, Elliott, and Nagel (1986) report that current science textbooks for the elementary grades cover a wide range of topics but none in much depth, omit discussion of most ethical and environmental issues, and do not interrelate the science topics

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either across the main science areas or from one grade level to another. Moreover, the teaching-learning activities introduced in these programs place the main emphasis is on reading and memorizing information, following cookbook-style recipes for hands-on activities, and practicing relatively low level science process skills, even at the upper grade levels.

Among the conclusions of three studies of the science curriculum sponsored by the National Foundation, Helgeson, et al. (1977), Weiss (1978) and the previously cited study by Stake and Easley (1978) are these: the science curriculum is the content included in relatively few textbooks, teachers make the textbook the "answer place" for teacher questions--both those used in discussions and those used in examinations, audio visual materials are supplements to information in textbooks that mainly present the same information, students are trained to seek "right" answers in a textbook, textbooks tend to focus the content of the science disciplines and emphasize words and specialized terminology.

Yager (1083) points to the importance of terminoloty in science education and Brandwein (1981) writes that most instruction in science centers on the mastery of unique words and terms with little attention to the real understanding and use. He also found no evidence that science in its most basic sense is ever approached in school science and that laboratories involve largely a verification of what students have been told in class or what they have read in textbooks: there is no evidence that students ever experience one real "experiment" throughout the school program.

Writing in the National Science Teachers Association's What Research Says to the Science Teacher, Voelker (1982) holds that 90% of high school graduates are not scientifically or technologically literate. In a study of secondary biology textbooks, Hurd (196) reports that the "authoritarian teaching of science," found in many of these textbooks fail to exemplify "scientific attitudes," present "the very antithesis of scientific attitudes and modes of thought," and often present theory and fact as if there were no difference between them "and as though both were settled for all time." In many courses and textbooks subjects are presented as though the course or textbook contained all the available facts and theory on the subject at hand, when, in fact, no book or course can present more than a selection of fact and theory. . . ."

Hurd concludes that the authoritarian teaching of science "does much to close minds, not open them; to make robots, not thinkers; to discourage, not encourage further work in science; to inhibit, not promote attempts to apply scientific methods to the numerous problems one meets daily in every walk of life." In contrast, "the best books and the best teaching show clearly that science is a search for knowledge and that mankind is very far from the end of the search in any branch of science; they inspire both a love of learning and a zeal for the quest." (Hurd, p. 119) According to Hurd, science textbooks should: (1) show the difference between fact and theory, between the solid core of verified knowledge and on-going intellectual exploration, between reaffirmed theory and the continuing re-evaluation of interpretations (If students are reminded that what there are reading is the present state of knowledge or observations and experimental results, they will be much more likely to think of science as a process as well as a more or less organized body of observations and explanatory theories); (2) make

very clear that the course is a selection of presently known fact and more or less accepted theory; (3) cite unsolved problems; and (4) show the relationships of the given subject to other fields of science and to broad problems of humanity.

The criticism of science textbooks has been extended to the college level. In his discussion of "The Art of Great Science," Rigden (1983) writes that "scientific knowledge is the overriding concern of textbook writers; the quest for that knowledge is ignored. Thus, since science is the quest, a distorted picture of science emerges from the pages of textbooks. Unfortunately, science education is based almost exclusively on general textbooks." Rigden says that science teachers have been extremely clever:

> they have designed simple, interlocking, logical units that enable the earnest student to rebuild, step by step, the intellectual edifice that is the current state of scientific knowledge. . . . Teachers are assisted in their task by textbooks . . . . [in which are] meticulously laid out the substantive content of science. The student is lead with unerring precision along a smooth and straight line of development. Each idea is made to lead to the next with apparent ease and inevitability. A perceptive student can easily anticipate what comes next. There is no mystery; there are no surprises.

Moreover, Rigden asserts that, typically, the history of science is not presented in science textbooks so that "science students do not catch glimpses of scientists as people, nor are they provided with the contextual framework in which a creative step is taken." The voices of those "who adhered to competing theoretical viewpoints is forever silenced, and, in that deceptive hush the assumption is encouraged that the evolution of scientific thought is smooth and unerring. . . . that a step taken by a scientist one day could just as well be taken by another scientist the next day . . . ." Rigden leaves us with a rhetorical question: "Why require a subject that is taught merely as the logical manipulation of factual information? The legacy of such an education experience is meager. Factual information is quickly forgotten, and the student's logical faculty is left with nothing to manipulate."

In introducing the Science Curriculum Improvement Study, Karplus (1965) asserts that there is general agreement that teaching practices do not meet the pupils' needs for two reasons: (1) a conflict in goals, with "science educators advocating mental flexibility and independence while teaching practice seeks to transmit traditions of knowledge and culture--traditions that are certified by authorities and are not to be questioned," and (2) a conflict in psychological and educational theory, with educational practice "reflecting a view [of fixed intelligence and predetermined development] that robs science teaching of its scientific significance." The one great weakness of current practice seems to be an almost exclusive reliance on textbooks and other such authoritative sources of information that are "quite impotent compared to the direct experiences that nourish the pupils' intellectual development of 'common sense" rationality. Instead of guiding this development in the direction of modern scientific understanding, therefore, the present-day science courses create a second, separate relatively abstract structure which is not used outside the school situation and which eventually atrophies."

In those cases where the presentation of science content through prose passages may be appropriate those passages should be considerate of the reader. Anderson (1984) lists some characteristics of "considerate" science textbooks. Above all, the structure of the science ideas and text, the sequencing of topics within and across grade levels, the introduction of new words, the inclusion and design of graphics, and the learning activities "should be consistent with the structure" of the science disciplines being represented. In addition, the science explanations should (a) "be clear enough to make sense, (b) require little or no new knowledge to understand them, and (c) make links to what the students already know." Finally, "the relationship between the ideas in the text and the learning activities shoul be relevant and clear" and the learning activities "should be described in enough detail so that the teachers and students can figure out how to do the activity and why it is important."

What Is Scientific Literacy?

The concept of "scientific literacy" has been discussed by a number of writers. Pella, O'Hearn, and Gale (1966) carried out an extensive study "to determine the referents included in the literature pertaining to scientfic literacy," or "science and effective citizenship." In the conclusion of their report, "the scientifically literate individual presently is characterized as one with an understanding of (1) basic concepts in science--including a language for communication and key concepts or conceptual schemes, (b) the nature of science, (c) the ethics that control the scientist in his work, (d) the interrelationship of science and society, (e) interrelationships of science and the humanities, and (f) the differences between science and technology."

Karplus (1963) defines the "functional understanding of scientific concepts," or scientific literacy, as the ability "to use scientific information obtained by others, to benefit from the reading of textbooks and other references" on the basis of "a conceptual structure and a means of communication that enable him to interpret the information as though he had obtained it himself." Helping students to construct a "conceptual framework that permits them to perceive the phenomena in a meaningful way and to integrate their inferences into generalizations of greater value than they would form if left to their own devices" should be the main objective of the elementary science curriculum. This does not mean that a pupil can learn only what he has observed: "the world is too complicated to permit a single individual to learn all that he should in a single lifetime." It does mean, however, is that the early years of school should present a "diversified program based heavily on concrete experiences" and presented in such a way that "helps to build a conceptual framework." Then, and only then, will the early learning "for a base for the assimilation of experiences that come later, experiences that may involve direct observation or reports of observations made by others.

Gagne (1968) describes the main goal of the Science: A Process Approach (SAPA) program as "not an accumulation of knowledge about any particular domain, such as physics, biology, or chemistry, but competence in the use of processes that are basic to all science." He holds that "the sixth grader who has learned science processes in [the SAPA manner] should be capable of studying science in the higher grades in a manner which is not now possible . . . [and] to learn about any given science, presented in accordance with

its theoretical structure, in far less time than otherwise would be required. Certainly he should have a better conception of science as a way of thinking and discovering."

The characteristics of "the scientifically literate individual" summarized by the National Science Teachers Association in an article on the Conferences on Scientific Literacy (NSTA, 1968) are listed in Exhibit 1.

[Place Exhibit 1 about here.]

Here we see heavy emphasis on what is termed the "affective domain," but which in fact contains much cognitive content (e.g., acquiring knowledge, understanding that, realizing, etc.)

Thus, science educators must be concerned with two dimensions of scientific literacy: (a) knowledge of certain science content--"understandings" and "appreciations" and (b) the processes by which individuals may be helped to construct the concepts and principles that make up this knowledge or these understandings. Because of restrictions inherent in the prose format, as well as in such other factors as marketing considerations, textbooks by themselves may not be able to supply as much of the elementary science curriculum as current expectation would have them. This limitation of the textbook appears to have been on the minds of the drafters of the Science Framework for the state of California. In describing a "model of expectations for learners' achievement in science," which is intended to serve as a major source of criteria for textbook selection in its Science Framework Addendum, the California State Department of Education (1984) asserts that "certain science concepts and skills are basic to scientific literacy--to a rational understanding of ourselves and our surroundings--and that these concepts and skills need to be addressed appropriately at several developmental levels. It is also vital tht the development of attitudes and values, rational thinking processes, and manipulative and communication skills should take place in close association with the development of concepts." [emphasis in the original]

So far, so good. However, the authors write further that, in this Addendum, the science concepts to be developed are organized into "four overlapping grade level blocks," kindergarten through grade three, grades three through six, and grades nine through twelve, "to approximate students' developmental levels. The concepts have also been organized according to three main science areas--life science, physical science, and earth science" -- with an introductory section on the nature of science and technology as these fields relate to individuals and society. This method of organization, the authors point out, "has the advantage of familiarity," and "one should not infer" that this is "the best or the only way to organize science concepts in the curriculum or that knowledge [content] must provide the structure around which the curriculum is organized."

[Insert Exhibit 2 about here]

These science concepts must be introduced by having students engage in those science processes through which concepts are developed, refined, and interrelated as students move up through the grades. The introduction of these processes is sequential, as suggested in Piaget's (1970) developmental theory, so that each is introduced at the most appropriate level of cognitive development and the processes introduced at each succeeding level are inclusive of those introduced at previous levels.

Moreover, the information that is presented in textbooks is several times removed from its sources in the work of the scientists in the areas of life, earth, and physical sciences and the hybrids -- thus are more like cut flowers than like living knowledge that can grow and be applied to the understanding of many aspects of the world.

In addition, the print format of textbooks with its linear presentation of highly stylized information, interspersed with graphics and academic exercises, puts further limitations on the range and nature of the content and and learning activities. The typical school science textbook presents fragments of information that are arbitrarily selected, presented in cursory prose form, and intended to be memorized by students. Consider the following example.

[insert Exhibit 3 about here]

While this mode of presentation -- "considerately" written -- might be suitable for a summary or overview, it is certainly not appropriate to the task of helping young students acquire knowledge for the first time.

If they are to develop real understanding of the natural world, its connections with their everyday lives, and the interrelationships that have important bearing on policies, careers, etc., they must develop concepts and principles for themselves directly from that natural world. Before they can draw appropriate meaning from accounts written by someone else, students must be helped to construct meanings for themselves. They must build for themselves from the objects, events, and relationships of their immediate surroundings those concepts, principles, and skills that are necessary to the understanding of events and relationships that are remote in space and time. In recent years, textbook programs in science have left out this important step.

Curriculum Reform Projects of the 1960s and 1970s

Based on the premise that by substituting laboratory-oriented (or process-oriented) approaches for textbook approaches, it is possible to effect changes in what science is taught and how, the curriculum improvement efforts of the the 1960s and early 1970s set about producing instructional materials that reflected contemporary thinking about learning and instruction in science. At the elementary level non-textbook programs such as those produced by the Science Curriculum Improvement Study (SCIS), the American Academy for the Advancement of Science (Science: A Process Approach, or SAPA), and the Elementary Science Study (ESS) attempted to promote the development of scientific literacy by more accurately reflecting both the nature of the several sciences and current understanding of children's cognitive development. A major emphasis of these programs was on laboratory-type activities designed to guide learners in the development of science concepts and principles by employing processes that are both similar to those used by scientists and appropriate to the stages of cognitive development, as suggested by Bruner (1963).

Welch (1980) summarized the main characteristics of these new curriculum products as follows. They contained: (1) modernized content, (2) a variety of integrated learning aids lending richness and flexibility, (3) provisions for doing science (inquiry, scientific process, problem-solving) through "hands-on" experiences designed to help students gain greater insights into the basic concepts of science, (4) thematic foci (e.g., the SAPA "process approach").

Although the goals of the "scientist-oriented" science programs were unimpeachable, they represented significant departures from the ways in which school subjects are usually taught at the elementary level. During their first decade, writes Welch (1980) these programs faced significant barriers. Among these were "the challenges of unprepared and insecure teachers," particularly at the elementary and junior high levels, the inherent difficulty of change, a lack of federal policy for innovations, the "natural conservatism" of the schools, and the threat of a national curriculum. Additional barriers that arose in the second decade were declining enrollments, inflation, student unrest, "fading public image of science," environmental concerns, competing demands (e.g., desegregation), and the "back-to-basics movement."

In another discussion of the problems involved, Duschl (1985) writes that, contrary to inferences made by the National Academy of Science and Engineering that the failure of first NSF efforts to improve precollege science instruction was caused by the implementation strategies used by educators and school systems, those who were in charge of these projects "ignored concomitant developments in other fields that held significance for what was being done with the development of science curricula." Typically, curriculum project teams included teachers and administrators but were run by scientists and the role of teachers and administrators was primarily to provide feedback to the scientist-writers, who were said to be reluctant to take criticism from school teachers unless they could furnish highly persuasive evidence to support it. Welch (1980) also reports a reluctance on parts of scientist writers to accept revisions suggested on the basis of classroom trials and that "more often than not, decisions on revisions were based on debates and arguments among the project staffs." In addition, writes Welch, commercial publishers were selected to print and market materials from nearly all the projects. "Thus . . . the private sector was, again, a factor in the determination of the science curriculum delivered to the nation's youth." Although he found no research on this point, Welch says that "conversations with those involved in the negotiations between the study groups and the publishers suggested that publishers did have influence on the new materials, particularly their format, and certainly on the way in which they were marketed."

In any case, the goals and objectives, topic coverage, and teacher-student roles were so different, of these new programs did not fit the conventional view of what should take place in classrooms. In addition, they required more teacher preparation time for ordering needed materials and setting up classroom laboratories and more classroom time to carry out than the traditional textbook approach to science instruction. In short, all the appealing features of the new science programs were no match for the cumulative effect of years and years of accepted practice in the basic subjects of the elementary school curriculum. Welch summarizes what we found out from that era, namely, that (1) the resources of the the science profession could be marshalled and directed toward a perceived problem in the schools, (2) considerable curriculum development ... occured and ... dominated the attention of the science education profession, (3) the educational system is extremely stable and efforts to change it have little effect, (4) curriculum effects account for very little of the [measured] variance in student achievement. "In spite of the expenditures of millions of dollars and the involvement of some of the most brilliant scientific minds, the science classroom of today is little different from the one of 20

years ago. While there may be new books on the shelves and clever gadgets in the storage cabinet, the day-to-day operation of the class remains largely unchanged. A teacher tells his or her students what s important to learn and so the class progresses."

Procedures

In order to determine the extent to which recently published textbooks appear to promote scientific literacy, nine elementary school (K-6) textbook series and one non-textbook program were analyzed. These programs all have copyright dates ranging from 1984 through 1986 and represent the main science instruction that students in elementary schools across the nation will receive for the next five or six years.

The ten programs were analyzed on five characteristics derived from the definition of scientific literacy discussed above, characteristics involving the treatment of: (1) content coverage in life science, earth science, and physical science, (2) topics dealing specifically with the nature and methods of science, (3) topics relating science to technology and to society, (4) content organization, with special attention to sequencing, and (5) student use of science processes through hands-on activities appropriate to their levels of development.

Findings

1. **Science Topic Coverage.** The results of the analysis of content coverage show that the nine programs cover a rich array of very similar topics selected from the life sciences, earth sciences, and physical sciences. However, the programs do differ on the amount of emphasis given to particular topics and subtopics, and serious questions can be raised as to whether many of the textbook topics are covered in sufficient depth to engender real understanding on the part of students. The one non-textbook program covers fewer topics in greater depth.

In life science all but one program emphasize plants and animals and all but two programs emphasize ecosystems.[1] A scattering of texts emphasize health and safety, human body systems, cells, and protists. Not surprisingly, controversial topics such as human reproduction and evolution are largely avoided.[2] Only one series provides more than cursory coverage of human reproduction; two others provide separate sets of overhead projector transparencies with schematic representations of the male and female reproductive systems. In dealing with evolution, one series describes changes over time at grades one, three, four, and five, and four pages at grade five also present Darwin's theory. Although two other programs do discuss adaptation for survival and natural selection, neither mention the term evolution. None of the other programs deal with evolution at all. The one non-textbook program gives little or no attention to cells, genetics, protists, and humans.

At least three of the four main earth science topics, astronomy, geology, and meteorology, are consistently covered in most of the textbook programs. The fourth topic, oceanography, tends to be deemphasized. While it was not unusual for a series to cover particular earth science topics at each grade (the spiral presentation of astronomy in one series is particularly notable), many tended to cover a topic at certain grade levels

only (for example, in one case meteorology is presented at grades one and two, and then not again until at grade four). The non-textbook program presents some meteorology and oceanography in grade 3 and astronomy in grade 4.

The physical science topics most consistently emphasized in the ten programs are matter, mechanics, electricity, and magnetism. Energy is also covered, although some series feature a combination of energy topics--heat, sound, light, and energy sources and transformations. The non-textbook program introduces aspects of all these topics, omitting only sound.

2. **Nature and Methods of Science.** There is no denying most of the published programs do give some attention (some more than others) to describ the process, in all but two (one textbook and the one non-textbook programs) this attention is spotty at best in the narrative passages and not at all well illustrated through the hands-on activities, which are mainly recipes to follow rather than examples of inquiry. Two thirds of the textbook programs include sections with titles such as "people in science," but there is no agreement on which people to include: some use these sections to describe science-related careers, others include sketches on contemporary scientists, and a few mention scientists from the past in connection with reports on the discoveries they made. However, there is virtually no account of the history of science or the impact of key scientific discoveries or formulations on human society and history. Finally, no clear and consistent picture emerges in any of the textbook programs of the tentativeness of scientific knowledge and the continual process of retesting and revision. In contrast, although it contains no mention of specific scientists and the history of science, the non-textbook program places major emphasis on the methods and approaches of the scientist.

3. **Science, Technology, and Society.** Here again, the findings are spotty. There are occasional textbook passages where the relationship between science and technology is described (e.g., between atomic theory and research and the development of atomic power and atomic weapons, or between the work of Pasteur and subsequent medical practice). Also include is some mentioning (but little extended discussion) of a very limited number of ethical and environmental issues and problems, but these are ones that arise from the application of technology: most programs at least touch on environmental pollution and the exploitation of natural resources (and the need for conservation); three programs deal with endangered species. Other issues are raised only infrequently, with brief mention of endangered animal species, toxic waste disposal, and the potential dangers of nuclear energy scattered across several programs. There is little or not encouragement given by the textbooks to go out into local communities and study any of these problems first hand. Although there is more stress on study of the students' immediate environment in the non-textbook program, it does not go any more extensively than the others into ethical and environmental issues.

Implicit in the treatment of science and society topics in the ten programs is the desire on the part of the publishers to avoid controversy, which could explain why coverage of many important issues is omitted. This does not, however, explain why little attention is given to the nature of the various science areas and especially to the possible limitations of the sciences in probing unanswered questions and solving the world's problems.

Careers in scientific and technical fields are described in most of the nine programs together with biographical sketches of some scientists (mainly contemporary). However, the instructional effectiveness of these features is diminished since they are not related directly to the narrative content. With rare exceptions, most of these biographical and career features appear on separate pages at the ends of chapters or units. This has the effect of tagging on short descriptions of people in science careers for the purpose of acknowledging women and minority roles in science rather than integrating particular careers or the lives of particular scientists with the discussion of the science topics being presented in the main text narrative or (perhaps most important) illuminating the particular roles and methods that are involved. The non-textbook program makes no direct mention of science-related careers.

4. **Content Organization.** In the textbook programs the sequencing of topics from lower to higher grade levels mainly follows a pattern of simple to more complex and concrete to more abstract. For example, plant and animal life, the solar system, and nutrition are topics that get increasingly more complex treatment. Significantly, however, the primary mode of presentation of all the textbook programs is through captioned pictures (in the early grades) or narrative passages accompanied by illustrations (in the later grades) often accompanied by hands-on activities or demonstrations to illustrate the points made. Although students are often encouraged to engage in science processes (e.g., observing, sequencing, measuring, comparing, describing), processes which are relevant to the formation of concepts and principles, the major thrust of the textbooks is on the presentation of the words that represent the concept, together with definitions and examples, rather than on directly promoting concept formation and using the verbal labels as guides and aids to communication. In contrast, the non-textbook program is structured entirely around a spiral sequence in which certain science concepts and processes are followed all the way through the grade levels at increasingly higher conceptual levels.

With the exception of one program, the textbook for each individual grade level of these kindergarten through grade 6 programs appears to be designed to stand on its own so that it can be used whether or not students have been exposed to previous levels. In eight of the nine textbook programs there is not direct mention or review of topics that have been presented earlier. In addition, the treatment of earth science, physical science, and life science as discrete areas. Only occasionally were topics from the three sciences directly related within textbook chapters or units (for example, a description of the structure of matter at the opening of a geology chapter). The result is that students are not given important insights into the ways in which the various scientific disciplines support each other in helping us to understand the workings of the physical and biological world. In several of textbook programs the chapter outline within levels illustrates a characteristic of "inconsiderate" organization. For example, the sequence of life science chapter titles for the third grade in one series is as follows: What Plants Need, Molds, Earthworms, Tigers, Trash and Litter, and then Health and Safety (Your Body, Food and You, Your Teeth, and Bicycle Safety). In the non-textbook program, topics related to earth science are consistently combined with either physical science or life science topics and the whole approach leads to the building of concepts which are common to several science areas.

5. **Teaching-Learning Activities.** All nine textbook programs were notable for their reliance on the traditional didactic approach to instruction. These programs appear to be based on the assumption that students should mainly attend to teacher presentations, read textbook passages, participate in teacher-led discussions, answer questions from the textbook and teaching plans, complete worksheets, and carry out hands-on activities as directed. Both the student textbooks and teacher lesson plans give students a mainly passive role as receivers and memorizers of information rather than as active seekers of answers to important scientific questions, although some programs did offer follow-up suggestions for keeping records of observations, writing reports, taking field trips, and caring for living things.

Although many programs were full of activities that were relevant to the narrative content and often very interesting, they usually substituted a cookbook recipe format aimed towards specific known results rather than opportunities to engage in open-ended scientific inquiry. For example, in one fifth grade text students are told that bird bones are hollow and that this helps them to fly. Then, an experiment several pages later has students examine chicken bones and concludes with the question, "What feature of a bird's feathers helps it to fly?"

In essence then, the hands-on activities in the nine programs were mainly designed to illustrate statements made in the text narrative rather than to provide occasions for students to develop concepts, explore problematic situations, to design approaches to finding solutions, to formulate and test hypotheses, and to look critically at the design of their studies and the methods they employ. In contrast, the non-textbook program is built around hands-on activities and emphasizes guiding students to the formulation of their own conclusions based on observations they make and experiments they carry out (and often design).

Summary

An examination of the current elementary school science textbook programs shows that, although they cover science content, they do not promote or encourage the development of scientific thinking or attitudes; nor do they engage students in applying the cognitive processes that are basic to understanding the content covered. If teachers use these programs to teach science without drawing on supplementary resources, students will understand science mainly as a collection of conclusions to be memorized: they will not be brought to an adequate understanding of the nature and methods of science nor will they be afforded sufficient opportunities to explore the relationship of science to technology and to the problems of living in the modern world.

In each of the nine recently published elementary school science textbook series the presentation of science processess either follows the narrative topics or individual processes are treated as just another topic. The main emphasis in these programs is on topic coverage, on remembering facts and generalizations presented in the text narrative, and on carrying out cookbook-style laboratory-type activities that have predetermined outcomes and serve as illustrations rather than experiences with scientific inquiry. Little attention is given in these series to such important themes

as the application of science concepts and skills to daily life, science in history, the relating of information on science careers directly to the main science topics, or the in-depth investigation and discussion of important science-related personal and societal problems and issues. In short, the emphasis of the content and the teaching and learning activities of these textbook programs is on the products of science rather than the nature and processes of science -- which has been the major complaint critics have directed at school science instruction for several decades. Little attention is given to the fundamental canons and methods of scientific inquiry, the attitude of objectivity, that is, to the pursuit of scientific literacy.

Conclusion

When we contrast textbook science with inquiry-oriented science, we are comparing the two main alternative approaches to answering the question of what science education is most appropriate. Judging from the positions taken by most of the authors reviewed earlier, the choice appears to come to one between promoting scientific literacy or scientific illiteracy in our schools.

If we want to give the children of this nation a good grounding in scientific literacy, either the elementary school science programs must transcend their heavy dependence on the textbook or science textbooks must be revised to include more of the teaching strategies and learning approaches that promote this literacy. Elliott and Nagel (1986) have suggested that teachers can do this by combining elements from published textbook programs, laboratory-oriented programs, and local resources and activities to produce a richer local science curriculum than can be achieved by using any one of these sources alone. In this approach, which is implied in the California Science Addendum (California State Department of Education, 1984), has textbooks continuing provide survey-style coverage of important science findings, with laboratory-oriented programs can contributiing important experiences with the processes of scientific investigation, and certain local resources and teacher-devised activities demonstrating the relation of science to everyday life as well as filling in gaps not covered by other materials. This augmentation process could have to be promoted through the organization building or district level committees where teachers work together to supplement the textbook programs they use; it would certainly require a concerted inservice staff development effort in which many teachers would be taken through a kind of "re-learning" of the concepts and processes of science in order to achieve higher levels of scientific literacy themselves.

The initiative for any significant changes in elementary school science programs will have to come from teachers and school districts. If textbook revision or augmentation is to take place, it will be throught the combining the best of the textbook and non-textbook programs into a fresh synthesis, but teachers and curriculum specialists backed up by policy makers at various levels must take the first important steps. Producers and consumers -- textbook publishers, educational leaders, teachers -- must collaborate in developing and implementng approaches that draw upon the best that each has to offer.

Notes

1. "Emphasized" means that there were at least one or two full chapters at most grade levels devoted to a topic.

2. This study was completed before publishers of these nine elementary (K-6) level textbooks and publishers of ten science textbook programs for the junior high level made revisions in their programs in response to action by the California State Department of Education requiring more adequate treatment of human sexual reproduction, evolution, and certain topics involving ethical and environmental issues.

List of Textbooks Analyzed

ADDISON-WESLEY SCIENCE (1984)
Coronado, SCIENCE AND TECHNOLOGY (1985)
Delta, SCIIS (1985)
HBJ SCIENCE (1985)
HEATH SCIENCE (1985)
HOLT SCIENCE (1986)
McGraw-Hill, GATEWAYS TO SCIENCE (1985)
Merrill, ACCENT ON SCIENCE (1985)
SCOTT, FORESMAN SCIENCE (1986)
SILVER BURDETT SCIENCE (1985)

Exhibit 3

Fossils: Things left from the leaves, bones, or shells of plants or animals that lived long ago.

When you finish this section, you should be able to:

☐ **A.** Explain what a *fossil* is.

☐ **B.** Describe ways that *fossils* are made.

In this rock, there are many things that look like shells. These shells are examples of **fossils** (**fahs**-silz). *Fossils* are things that are left from plants and animals that lived a long time ago.

Let's find out how these shells became fossils. A long time ago, the animals that lived in these shells were alive. They lived at the bottom of the ocean. The animals in the shells died. The shells became covered with sediment. As the years passed, the sediment hardened into rock. Even when the shells were no longer there, copies of them were still in the rock.

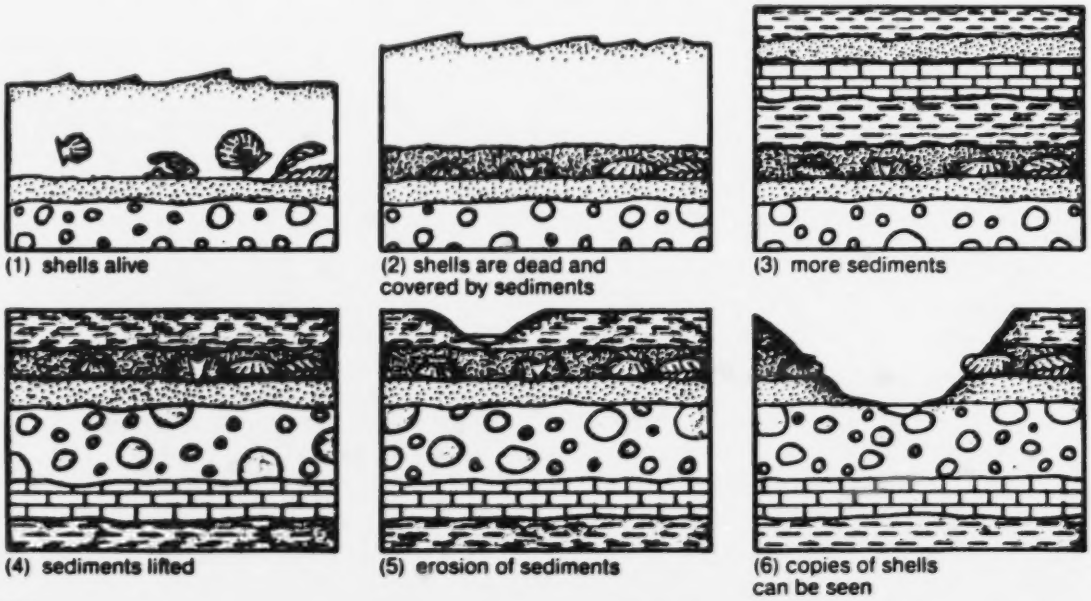
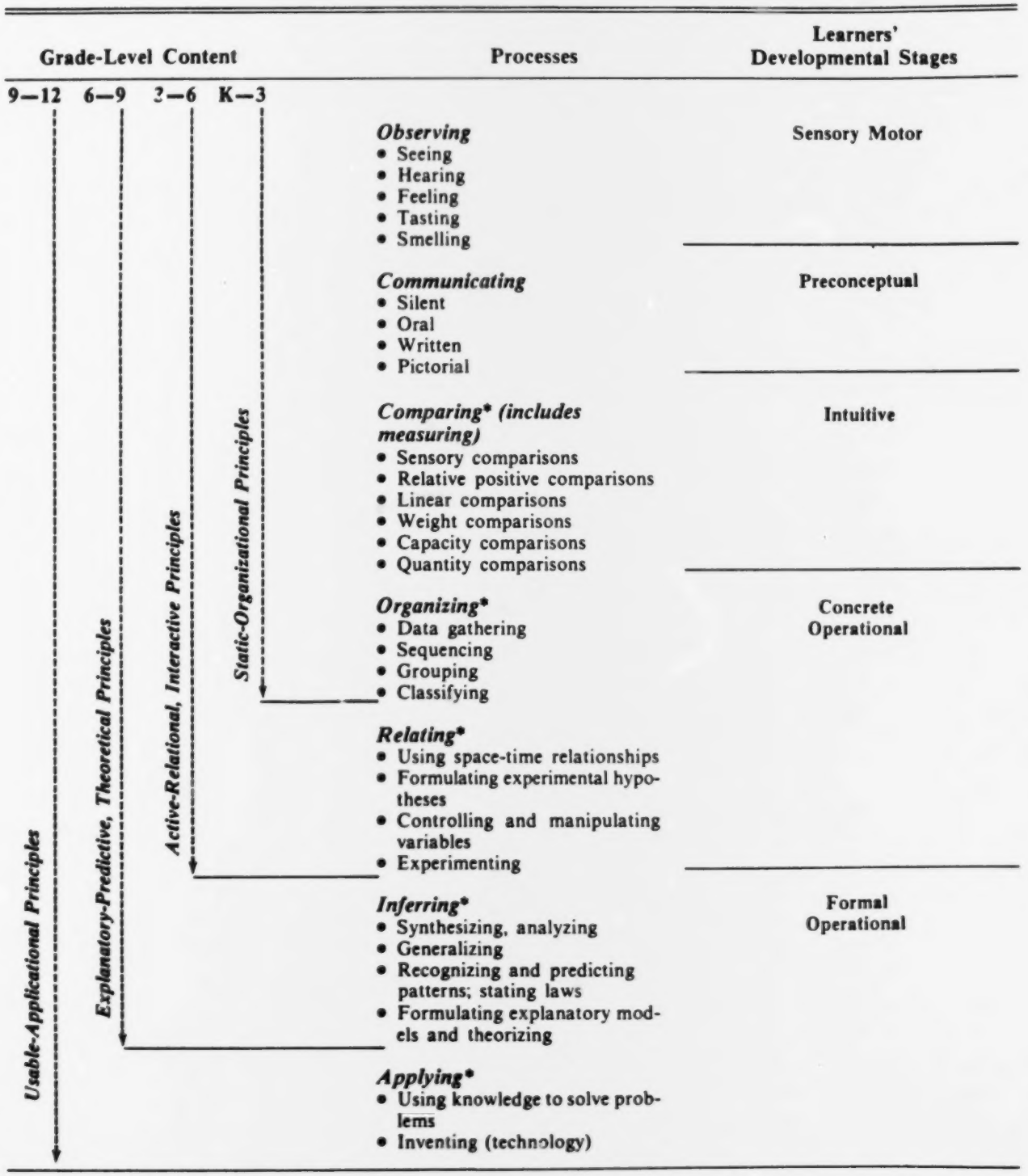

(1) shells alive
(2) shells are dead and covered by sediments
(3) more sediments
(4) sediments lifted
(5) erosion of sediments
(6) copies of shells can be seen

Exhibit 3

Science Process/Content and Developmental Stages, CSDE (1984)



*These processes include the application of appropriate mathematical concepts and skills in interpreting data and solving problems.

Exhibit 1.

Scientific Literacy*

Cognitive Domain: The scientifically literate individual will:
have more than a common-sense understanding of the natural world.
be in intellectual possession of some of the major concepts, laws, and theories of the several sciences.

Affective Domain:
Awareness of conditions. The scientifically literate person:
acquires knowledge of science careers
appreciates the interaction of science and technology
understands that science is generated by people with a compelling desire to understand the natural world
recognizes that science grows, possibly without limit
recognizes that achievements of science and technology properly used are basic to the advancement of human welfare.
recognizes that the meaning of science depends as much on its inquiry process as on its conceptual patterns and theories
understands the role of scientific enterprise in society and appreciates the cultural conditions in which it survives.

Acceptance of values. The scientifically literate person:
rejects myths and superstitions.
displays the habit of weighing evidence
realizes that science is a basic part of modern living

Preference for values. The scientically literate person:
exhibits curiosity, patience, persistence, open-mindedness, tolerance, willingess to be convinced by evidence, confidence in the "scientific method"
subscribes to "the search for truth," "the importance of of science for understanding the modern world," "the value of methods and procedures of science
appreciates the men who add to the storehouse of knowledge
recognizes the intellectual satisfaction to be gained from the pursuit of science
shares the excitement of discovery, the desire to be creative, faith in the logical processes of science
enjoys science for intellectual stimulus, beauty of explanations, the pleasure from knowing, and the excitement of discovery
appreciates the importance of narrowing the gap between frontier research and the popular understanding of new achievements

* National Science Teachers Association, "Conferences on Scientific Literacy." The Science Teacher, 35:30-32, May 1968.

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